CENTRAL VALLEY FLOOD MANAGEMENT PLANNING PROGRAM

FloodSAFE CALIFORNIA

Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley

Version 4

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STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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1.0 Purpose

The purpose of this document is to provide interim analytical and procedural criteria for civil engineers, cities, and counties to follow in meeting the requirements of California's Government Code Sections 65865.5, 65962, and 66474.5 with respect to finding that levees and floodwalls provide protection against a flood that has a 1-in-200 chance of occurring in any given year. These interim levee design criteria (ILDC) apply to urban and urbanizing areas of the Sacramento-San Joaquin Valley until such time these criteria are superseded by a subsequent version or become regulations in the California Code of Regulations (CCR).

The ILDC were developed through a collaborative stakeholder involvement process with representatives from cities, counties, flood agencies, State of California (State) agencies, and federal agencies. The ILDC will continue to be refined before being finalized, most likely as regulations, by around 2013-2014. Even after being finalized, amendments may be needed from time to time.

2.0 Definitions

200-Year floodplain means an area that has a 1-in-200 chance of flooding in any given year, based on hydrological modeling and other engineering criteria accepted by the Department of Water Resources (DWR) (Government Code § 65300.2(a)).

Accreditation means recognition by the Federal Emergency Management Agency (FEMA) that a levee provides protection for the base flood (100-year or one percent annual chance) event, based on certification provided by a registered professional engineer or a federal agency with responsibility for levee design.

Adequate progress means all of the following:

a. The total project scope, schedule, and cost of the completed flood protection system have been developed to meet the appropriate standard of protection.

b. i. Revenues that are sufficient to fund each year of the project schedule developed in paragraph (a) have been identified and, in any given year and consistent with that schedule, at least 90 percent of the revenues scheduled to be received by that year have been appropriated and are currently being expended.

   ii. Notwithstanding subparagraph (i), for any year in which state funding is not appropriated consistent with an agreement between a state agency and a local flood management agency, the Central Valley Flood Protection Board may find that the local flood management agency is making adequate progress in working toward the completion of the flood protection system.

c. Critical features of the flood protection system are under construction, and each critical feature is progressing as indicated by the actual expenditure of the construction budget funds.

d. The city or county has not been responsible for a significant delay in the completion of the system.

e. The local flood management agency shall provide the Department of Water Resources and the Central Valley Flood Protection Board with the information specified in this subdivision sufficient to determine substantial completion of the required flood protection. The local flood management agency shall annually report to the Central Valley Flood Protection Board on the efforts in working toward completion of the flood protection system (Government Code § 65007(a)).

Assurance means the probability of non-exceedance.

Blanket layer means a top stratum of clayey and/or silty soil extending landward of the landside levee toe that has low vertical permeability in comparison to the horizontal permeability of deeper soils.

Board means the Central Valley Flood Protection Board (formerly The Reclamation Board).

Central Valley Flood Protection Plan (CVFPP) means a State plan that will describe the challenges, opportunities, and a vision for improving integrated flood management in the Central Valley. The CVFPP will document the current and future risks associated with flooding and recommend improvements to the State-federal flood protection system to reduce the occurrence of major flooding and the consequence of flood damage that could result. The plan is to be submitted by DWR to the Board by January 1, 2012, and adopted by the Board by July 1, 2012, and is to be updated every five years thereafter. The CVFPP is being developed under DWR's Central Valley Flood Management Planning Program.

Certification means a statement provided by a registered professional engineer that data submitted to FEMA supporting that a levee system complies with criteria specified in 44 Code of Federal Regulations (CFR) 65.10 for protection against the base flood (100-year or one percent annual chance) is accurate to the best of the engineer's knowledge. Alternatively, certification may mean that a federal agency with responsibility for levee design provides a statement that the levee has been adequately designed and constructed to provide protection against the base flood (44 CFR 65.10).

Civil engineer means a licensed civil engineer in the State of California.

Comprehensive Study means the 2002 Sacramento-San Joaquin River Basins Comprehensive Study. This study, led by the Corps, provided estimates of median 100-year, 200-year, and 500-year flows and water surface elevations using various scenarios or sets of assumptions regarding whether and when upstream levees are breached. One set of assumptions, which is the set assumed in these criteria, had levees act as weirs and allow overtopping flows without levee failure. This assumption is required by the Corps for National Flood Insurance Program (NFIP) levee system evaluations and is supported by FEMA in its levee system accreditations.

Corps means the United States Army Corps of Engineers.

Corps' risk and uncertainty (R&U) approach means the analysis of flood hazard in which the uncertainty of contributing factors is accounted for explicitly – especially uncertainty in hydrologic and hydraulic inputs and in levee performance. The R&U procedures considered herein are those described in the Corps' EM 1110-2-1619 and included in the Corps' HEC-FDA software application.

Creep ratio means the length of the seepage path along the line of creep divided by the maximum hydraulic head that could occur.

Critical gradient means the average head loss per foot of seepage traveling upward through a blanket layer at which seepage-induced movement of the soil particles will occur.

Critical infrastructure means the systems and assets, whether physical or virtual, that are so vital that their incapacitation or destruction may have a debilitating impact on the security, economy, public health or safety, environment, or any combination of these matters, across any federal, State, regional, territorial, or local jurisdiction.

Design Water Surface Elevation (DWSE) means the 200-year stage or water level used to design a levee or floodwall.

Developed area means an area of a community that is:

a. A primarily urbanized, built-up area that is a minimum of 20 contiguous acres, has basic urban infrastructure, including roads, utilities, communications, and public facilities, to sustain industrial, residential, and commercial activities, and

    i. within which 75 percent or more of the parcels, tracts, or lots contain commercial, industrial, or residential structures or uses; or

    ii. is a single parcel, tract, or lot in which 75 percent of the area contains existing commercial or industrial structures or uses; or

    iii. is a subdivision developed at a density of at least two residential structures per acre within which 75 percent or more of the lots contain existing residential structures at the time the designation is adopted.

b. Undeveloped parcels, tracts, or lots, the combination of which is less than 20 acres and contiguous on at least three sides to areas meeting the criteria of paragraph (a) at the time the designation is adopted.

c. A subdivision that is a minimum of 20 contiguous acres that has obtained all necessary government approvals, provided that the actual "start of construction" of structures has occurred on at least 10 percent of the lots or remaining lots of a subdivision or 10 percent of the maximum building coverage or remaining building coverage allowed for a single lot subdivision at the time the designation is adopted and construction of structures is underway. Residential subdivisions must meet the density criteria in paragraph (a)(iii) (Title 44 CFR Section 59.1 and Government Code § 65007(c)).

DWR means the California Department of Water Resources.

Early Implementation Program means the DWR program that funds critical flood risk reduction projects that will be initiated prior to adoption of the CVFPP. These projects represent "no regrets" types of projects that are likely to be consistent with an adopted CVFPP.

Encroachment means any obstruction or physical intrusion by construction of works or devices, planting or removal of vegetation, or by whatever means for any purpose, into any of the following:

a. any flood control project works;

b. the waterway area of the project;

c. the area covered by an adopted plan of flood control; or

d. any area outside the above limits, if the encroachment could affect any of the above. (Title 23 CCR, Division 1, Chapter 1, Article 2, § 4)

Exit gradient means the average head loss per foot for seepage traveling upward through a blanket layer.

Facilities of the State Plan of Flood Control means the levees, weirs, channels, and other features of the federal and State authorized flood control facilities located in the Sacramento and San Joaquin River drainage basin for which the Board or DWR has given the assurances of nonfederal cooperation to the United States required for the project, and those facilities identified in Section 8361 of the California Water Code (Public Resources Code § 5096.805(e)).

FEMA means the Department of Homeland Security's Federal Emergency Management Agency.

Finding means a duly adopted statement by a city or county, based upon substantial evidence in the record, pertaining to whether the urban level of flood protection exists for a specifically identified area of land (Government Code § 65865.5, 65962, and 66474.5).

Flood risk means the consequence of flooding as a function of negative outcomes that could result when flooding occurs (flood risk = probability x consequence).

Floodwall means a manmade barrier constructed of material other than soil along a water course for the primary purpose of providing flood protection.

Freeboard means the height of the physical top of levee or floodwall above the median 200-year water surface elevation.

Frequently-loaded levee means a levee that experiences a water surface elevation of one foot or higher above the elevation of the levee toe at least once a day for more than 36 days per year on average.

Hydraulic top of levee (HTOL) means the lower of either: (1) the median 200-year water surface elevation plus three feet, (2) the physical top of levee (or the water surface profile that matches the physical top of levee at its lowest point) if it is equal to or higher than the 95 percent assurance 200-year water surface elevation, it provides at least two feet of freeboard, and the Modified Corps Approach is being used, or (3) the median 500-year water surface elevation.

Interim levee design criteria (ILDC) means the levee and floodwall design criteria developed by DWR for providing the urban level of flood protection (Government Code § 65007(k) and California Water Code § 9602(i)).

Intermittently-loaded levee means a levee that does not experience a water surface elevation of one foot or higher above the elevation of the levee toe at least once a day for more than 36 days per year on average.

Levee means a manmade barrier constructed of soil along a water course for the primary purpose of providing flood protection.

Levee system means one or more discrete reaches of levee and/or floodwall and other flood management structures along one or more streams that together provide flood protection to a common, defined area (i.e., the protected area).

Levee toe means the most landward point of the levee where the landside levee slope, or constructed landside berm, meets natural ground.

Median water surface elevation means the best estimate for the stage associated with the median flow for a given frequency. Median flow is as defined in the Guidelines for Determining Flood Flow Frequency, Bulletin 17B of the Hydrology Subcommittee (Interagency Advisory Committee on Water Data, 1982). The median flow for a given frequency may be estimated with standard procedures, including fitting a statistical model with unregulated streamflow observations; configuring, calibrating, and applying a watershed runoff model with design precipitation; or applying regional regression equations acceptable to FEMA, Caltrans, the Corps, or DWR. In determining the median water surface elevation, all levees in the region and upstream from the region are assumed to act like weirs and not breach when overtopped.

Non-project levee means a levee or floodwall that is not a project levee.

Non-urban area means a developed area or an area outside a developed area in which there are fewer than 10,000 residents (Government Code § 65007(e)).

Penetration means a crossing through a levee or floodwall by a pipe or other structure.

Periodic review means an inspection, and review of pertinent maintenance records, inspection records, and correspondence, performed by a civil engineer and documented in a report no less frequently than once every five years. The periodic review is performed to assess whether damage or degradation has occurred, or maintenance inadequacies have been identified, for a levee and/or floodwall system that would compromise its ability to provide the urban level of flood protection as defined by the ILDC in effect at the time of the most recent finding by the city or county.

Project levee means a levee or floodwall that is a facility of the State Plan of Flood Control, as defined in Public Resources Code § 5096.805.

Relief cut means a breach in a levee that is made by excavation or blasting that provides for evacuation of flood waters from within the protected area back to a stream or bypass.

Sacramento-San Joaquin Valley means any lands in the bed or along or near the banks of the Sacramento River or San Joaquin River, or any of their tributaries or connected therewith, or upon any land adjacent thereto, or within any of the overflow basins thereof, or upon any land susceptible to overflow therefrom. The Sacramento-San Joaquin Valley does not include lands lying within the Tulare Lake Basin, including the Kings River (Government Code § 65007(g)).

State means the State of California.

State-Federal Flood Protection System means the collective works or facilities of the State Plan of Flood Control (California Water Code § 9602(c)).

Urban area means a developed area in which there are 10,000 residents or more (Government Code § 65007(i)).

Urbanizing area means a developed area or an area outside a developed area that is planned or anticipated to have 10,000 residents or more within the next 10 years (Government Code § 65007(j)).

Urban level of flood protection means the level of protection that is necessary to withstand flooding that has a 1-in-200 chance of occurring in any given year using criteria consistent with, or developed by, the Department of Water Resources (Government Code § 65007(k) and California Water Code § 9602(i)).

3.0 Need

State law enacted in 2007 (Senate Bill (SB) 5) calls for 200-year flood protection to be the minimum level of protection for urban and urbanizing areas in the Sacramento-San Joaquin Valley (i.e., the urban level of flood protection). Beyond 36 months after adoption of the Central Valley Flood Protection Plan, the new law limits the conditions for approval of development if adequate progress towards achieving this standard is not met (Government Code § 65865.5, 65962, 66474.5). Urban and urbanizing areas protected by project levees cannot use adequate progress as a condition to approve development after 2025. SB 5 requires that the urban level of flood protection be consistent with criteria used or developed by DWR (Government Code § 65007(k)). To avoid delaying urgently needed flood protection, interim levee design criteria are needed. The ILDC fulfill this need until they are revised and/or become regulations.

DWR reviewed current guidance and levee criteria by the Corps and FEMA. With the exception of hydrologic, hydraulic, and levee freeboard requirements, FEMA's levee design guidance contains no specific criteria and suggests use of various Corps documents. The Corps has developed most of the guidance needed for engineers to design levee systems, and most engineers in the nation who are involved in levee design and construction utilize that guidance. However, some important aspects of the Corps' guidance lack specificity, need to be modified, or are still under development (this is explained further in Section 4.0). Furthermore, there are no procedural criteria that would be applicable for engineers, cities, or counties in making a finding that the urban level of flood protection exists for an area.

Due to the changing state of practice and the absence of specific guidance from the federal government on some levee design considerations, DWR needs to provide interim guidance and criteria for design water surface elevations and levee design that will be used for:

- Evaluations of project levees in urban and urbanizing areas
- Evaluations of non-project levees in urban and urbanizing areas
- Guidance for urban and urbanizing area levee designs to be initiated/completed in the near future
- Eligibility criteria for urban Early Implementation Program grant funding[1]

[1] The citizens of California passed two bond measures on November 6, 2006 that provide $4.9 billion of bond funds for reducing flood risk in California. By 2020, approximately $2 billion of State bond funds is expected to be spent for improving urban flood protection in the Sacramento-San Joaquin Valley. Several urban areas in the Sacramento-San Joaquin Valley are receiving bond funding under DWR's Early Implementation Program.

- Assisting engineers, cities, counties, and local flood agencies in achieving FEMA 100-year flood protection

- Assisting engineers, cities, counties, and local flood agencies in achieving the urban level of flood protection

- Planning studies, such as the Central Valley Flood Protection Plan

4.0 Background

Except for some Sacramento Valley levee construction early in the 20th century by the Board and the bypass levees constructed by DWR in the 1960s on the San Joaquin River, the State has only built or improved project levees in the Sacramento-San Joaquin Valley by partnering with the Corps. In these partnerships the Corps set the design standard and constructed the levees accordingly. For the first time since the 1960s, the State is now in the lead in performing (or providing funding for local agencies to perform) new levee construction and improvements to existing levees. It is highly desirable to follow the Corps' design standards to provide consistency in system improvements, comply with existing standards, and to facilitate federal crediting. However, the Corps' levee design standards are evolving and some important aspects are not established in writing at this time.

Floodplain maps throughout the nation are being updated by FEMA under its Map Modernization Program pursuant to the procedures contained in Procedure Memoranda 34 and 43, issued in August 2005 and September 2006 respectively. These procedures require certification of the data supporting the adequacy of levees for protection against the base flood in order to maintain their current accreditation by FEMA (44 CFR Part 65-10). Project levees and appurtenant non-project levees in the Sacramento-San Joaquin Valley are being evaluated for geotechnical adequacy by DWR. The evaluations will be used to support planning studies and decisions, the design of repairs and improvements, and floodplain mapping studies. Sacramento-San Joaquin Valley communities desire to maintain, or regain at the earliest opportunity, accreditation of the levees affecting their communities – thereby allowing urban growth to continue and flood insurance to be optional instead of mandatory.

In addition to FEMA's requirements, SB 5 (i.e., Government Code § 65865.5, 65962, 66474.5) requires urban and urbanizing areas in the Sacramento-San Joaquin Valley to achieve, or have adequate progress toward, the urban level of flood protection within 36 months after adoption of the Central Valley Flood Protection Plan in order to continue development in the 200-year floodplain. Urban and urbanizing areas protected by project levees in the Sacramento-San Joaquin Valley will need to achieve the urban level of flood protection by 2025 in order to continue development in the 200-year floodplain. Consequently, an early goal of most Sacramento-San Joaquin Valley communities is to provide 100-year FEMA-level protection as an important milestone on the way toward achieving the urban level of flood protection. By having criteria for the urban level of flood protection while the levee construction is performed for achieving FEMA-level protection, the constructed features can be made compatible or expandable for achieving the urban level of flood protection.

In designing and certifying levees there are two commonly used approaches:

- **The FEMA Approach** – used by most civil engineers to certify and/or design levees for accreditation by FEMA, is a deterministic design approach based on the median 100-year water surface elevation. The levee must be analyzed for erosion, stability, seepage, and settlement based on this water surface and a minimum amount of freeboard (typically three feet) provided above this water surface elevation. As little as two feet of freeboard may be allowed if the uncertainty in flow and stage is characterized and justifies less than three feet of freeboard. Except for the last 10 to 15 years, the Corps typically used this deterministic approach also. In recent years, the Corps has been developing and using a combined probabilistic and deterministic approach. FEMA has been working with the Corps on the concept of transitioning from its current deterministic approach to the Corps' new approach.

- **The Corps' Approach** – developed and used by the Corps, is a combined probabilistic and deterministic approach that considers uncertainty in design water surface elevation, combined with a deterministic geotechnical levee evaluation. The Corps' procedure for certification, called a National Flood Insurance Program levee system evaluation, requires deterministic seepage and slope stability analyses and conventional factors of safety using the 90 percent assurance 100-year water surface elevation. The Corps' procedure for NFIP evaluations also requires at least three feet of freeboard unless the top of levee is at or above the 95 percent assurance 100-year water surface elevation and provides at least two feet of freeboard. It also requires that the hydraulic modeling assume that other levees in the region not fail, even when overtopped.

Because a completely probabilistic approach for developing the DWSE would consider and describe with a probability distribution all of the important uncertainties influencing the DWSE, the Corps' Approach to date in the Sacramento-San Joaquin Valley is more properly characterized as a conditional probabilistic approach: simplifying assumptions are made to fix values of some uncertain inputs in the risk and uncertainty analysis. In most cases, the simplifying assumptions introduce conservatism. The result is that the Corps' Approach described herein tends to result in water surface elevations with less likelihood of being exceeded than stated (i.e., a 90 percent assurance water surface elevation for a 200-year event actually has less than a 10 percent chance of being exceeded). This is also true for the FEMA Approach, since some conservative assumptions are employed in developing the median water surface elevation.

Historically, most of the levee failures in the Sacramento-San Joaquin Valley have been caused by slope instability or seepage (including underseepage). Such failures tend to occur rapidly and with little or no warning – leaving little opportunity for evacuation prior to flooding. On the other hand, failures caused by levee overtopping are foreseeable and such levee failures tend to progress more slowly, and in some cases can be prevented through aggressive flood fighting. Failures from overtopping provide much better opportunity to successfully evacuate the threatened area and to take steps to minimize damage to personal property. Consequently, although this is not a consideration in FEMA's 44 CFR 65.10, the Corps considers capacity exceedance in its NFIP levee system evaluations. Furthermore, for designing levees, the Corps has begun considering new criteria that require factors of safety for seepage and slope stability in excess of 1.0 for flood water at the top of the levee. The Corps has not yet established the minimum factors of safety or a definition for the top of levee, or evaluated the cost-effectiveness of this requirement to justify it in an economic analysis. Because it is primarily a life-saving and injury-reducing criterion, it may not be possible to justify it economically. Nevertheless, DWR supports this approach for levees that protect urban and urbanizing areas as a reasonable requirement for protecting life and personal property and provides detailed criteria for this approach later in this document.

Evaluation and mitigation for seismic performance of levee systems has generally had low priority in the past, except for levees with a high likelihood of having coincident high water and earthquake loading, such as many levees in the Delta. More current thinking is that intermittently-loaded levees should be evaluated for seismic performance using typical water surface levels and addressing the post-seismic flood risk through emergency response, interim and long-term repairs following the earthquake, and/or seismic remediation prior to the earthquake.

5.0 Guiding Principles

Guiding principles serve as the foundation for specific interim levee design criteria that follow in subsequent sections of this document. The ILDC are built upon Corps guidance, and to a lesser extent, FEMA guidance. Except for criteria specifically provided in this document, the guidance for levee and floodwall design provided in the Corps' EM 1110-2-1913, EM 1110-2-2502, ETL 1110-2-569, EC 1110-2-6067, the Geotechnical Levee Practice SOP for the Sacramento District, and other Corps guidance documents for the selected design flood event is considered to be applicable. The ILDC address three distinct cases:

- Existing guidance lacks some specific details
- Existing guidance is under development
- Existing guidance needs modification

5.1 Overall Design Principles

- To the extent applicable, the FEMA Approach is considered acceptable. However, the FEMA Approach is not explicit in some of its requirements and does not consider the consequences of failure in an urban area or the failure mode of the levee for events that exceed design.
- To the extent applicable, the Corps' Approach is considered acceptable. Most aspects of the approach can be utilized by the State and local agencies as a basis of design, with some modifications and clarifications.
- To the extent practical, sufficient right-of-way should be acquired to provide vehicular access along the landside levee toe, control activities that could impact levee performance, and to provide for future levee expansion should it be needed.
- Encroachments and vegetation should be evaluated and managed so as to not impact levee safety, while recognizing their benefits.
- With few exceptions, levee systems should be designed to perform without relying upon emergency actions, such as flood fighting.
- Future changes to the ILDC will need to be carefully evaluated for potential impacts on levee repair and improvement projects that are underway or have been completed recently.

5.2 Geotechnical Design Principles

- Urban and urbanizing area levees should be designed for a landside slope stability factor of safety greater than 1.0 (stable) for flood stages at the top of the levee so that erosion from overtopping would be the expected mode of failure for extreme flood events. However, there will be exceptions to this general rule where the physical top of levee provides more than the minimum required freeboard. By establishing design criteria based on the HTOL, these exceptions are considered to be acceptable and levee crown degradation (as a way of increasing the likelihood of overtopping before levee failure) is not encouraged.

- Performance of urban and urbanizing area levees and floodwalls during a seismic event with 200-year return period ground motions should be considered for existing levees as well as in the selection of all levee repair and improvement alternatives. Repairs or improvements primarily for the purpose of seismic strengthening generally would not be justifiable for intermittently-loaded levees. But there can be situations where such repairs or improvements are warranted. Otherwise, seismic remediation could occur as needed after the earthquake, pursuant to an appropriate emergency response and remediation plan.

- Frequently-loaded levees should have additional reliability, approaching that expected of dams, and should continue to function during and after ground motions from a 200-year return period earthquake.

5.3 Hydrologic and Hydraulic Design Principles

- Urban and urbanizing area levee and floodwall designs should assume that (1) other levees in the regional system upstream and downstream from the area do not breach, even when overtopped, (2) other levees in the regional system upstream and downstream from the area are no lower than their authorized design elevations, and (3) other urban levees in the regional system upstream and downstream from the area will have at least three feet of freeboard with respect to the 200-year water surface, which should be computed through appropriate analytical methods.

- Urban and urbanizing area levee and floodwall designs should consider the potential for sea level rise and climate change to increase runoff and peak stages over those calculated using previous hydrology and hydraulics studies, considering the physical limitations of the regional system. A sensitivity analysis of increased stream flows can be useful in evaluating how high the DWSE should be raised.

- Levees and floodwalls protecting urban and urbanizing areas should be designed as a system.

5.4 Procedural Principles

- The consequences of levee and floodwall failure in urban and urbanizing areas are too severe to completely rely upon the judgment of a single engineer or engineering firm for designing or evaluating a levee system and determining that it meets criteria for the urban level of flood protection. Accordingly, peer review by an independent panel of experts is needed.

- After approximately 2015, before cities and counties in the Sacramento-San Joaquin Valley can approve new development for urban and urbanizing areas within a flood hazard zone, they must first find, based on substantial evidence in the record, one of the following:

  - that the urban level of flood protection exists,

  - that adequate progress towards the urban level of flood protection is being made, or

  - that the city or county has imposed conditions that will protect the property to the urban level of flood protection.

- A finding by a city or county should not last indefinitely, nor should substantial evidence in the record be considered adequate if not updated. The finding should expire within a reasonable time period that provides enough time for stability in urban planning, but not so much time as to significantly jeopardize public safety in the area should standards, hydrology, sea level, or system performance change. Twenty years is generally considered to be a reasonable time period for the maximum life of a finding.

- Cities and counties should have flexibility to decide for themselves, based on their own unique circumstances, when to initiate renewal of a finding before it expires at the end of its 20-year life.

- When justified, based on new information and a compelling need to protect public safety, there should be some limited ability to require near-term application of new criteria during the 20-year life of a finding.

- Levee and floodwall operation and maintenance should be thoroughly reviewed periodically to address any damage or maintenance inadequacies.

- Civil engineers should have opportunities to deviate from prescribed criteria and use modified criteria where appropriate.

6.0 Interim Levee Design Criteria for Urban and Urbanizing Areas

6.1 Design Water Surface Elevation Criteria

Two options are offered for determining the Design Water Surface Elevation (DWSE) for urban and urbanizing area levee system design, summarized as follows:

- **A modified version of the FEMA Approach**: specifically, to perform geotechnical and structural analysis with conventional safety factors using the median 200-year water surface elevation as the DWSE, calculated through a conventional deterministic hydraulic analysis that assumes levees in and upstream from the region will not breach if overtopped. To provide for the primary hazard of levee failure to be from overtopping (rather than slope instability or seepage) when the DWSE is exceeded, the Modified FEMA Approach requires a geotechnical analysis using a water surface set at the HTOL. The physical top of levee or floodwall would need to be at least three feet higher than the DWSE, or higher if required for wind setup and wave runup.

- **A modified version of the Corps' Approach**: specifically, to perform geotechnical and structural analyses with conventional safety factors using the 90 percent assurance 200-year water surface as the DWSE, calculated through a conditional R&U analysis that assumes levees in and upstream from the region will not breach if overtopped. To provide for the primary hazard of levee failure to be from overtopping (rather than slope instability or seepage) when the DWSE is exceeded, the Modified Corps Approach requires a geotechnical analysis using a water surface set at the HTOL. The physical top of levee or floodwall would need to be at least three feet higher than the median 200-year water surface elevation if the 90 percent assurance 200-year water surface elevation is used to set the physical top of levee, or higher if required for wind setup and wave runup. The physical top of levee or floodwall would need to be at least two feet higher than the median water surface elevation if the 95 percent assurance 200-year water surface elevation is used to set the physical top of levee or floodwall, or higher if required for wind setup and wave runup.

In addition, under either option, civil engineers would be allowed and encouraged to adjust the DWSE upward to account for previous hydrologic studies in the Sacramento-San Joaquin Valley having a small number of storm centerings and not addressing climate change - until new hydrology is developed for the Sacramento-San Joaquin Valley that can be expected to yield higher flows than the current hydrology. The adjustment should be based on judgment and consideration of the physical limits of the upstream and nearby regional flood protection system.

For an urban area or urbanizing area, the entire levee system needs to be designed to provide a finding of the urban level of flood protection using only one of the two options.

The approach can follow either of the following two options:

Option 1: Modified FEMA Approach

The median water surface elevation from which the DWSE will be established should be computed using the median 200-year discharge rate for the design event at the site. Appropriately-configured channel models should be used for computation of the elevation that corresponds to that discharge, as described below. The median discharge rate should be determined from the best available results of recent flood-frequency studies. If results of a recent frequency study completed by the Corps or DWR are available, the median 200-year discharge rate from that study should be used. In the absence of an appropriate discharge rate from such a recent study, the 200-year discharge rate at the site from the 2002 Comprehensive Study may be used, if that is available. Finally, if an appropriate design discharge rate is not available for either a recent Corps or DWR study or the Comprehensive Study, the median 200-year discharge may be computed by the engineer with appropriate methods. Those methods include fitting a statistical model with unregulated streamflow observations; configuring, calibrating, and applying a watershed runoff model with design precipitation; or applying regional regression equations acceptable to FEMA, Caltrans, the Corps, or DWR.

1. The hydraulic models are to use the following assumptions:

    a. Upstream, downstream, and nearby levees and floodwalls protecting urban areas are assumed to be raised to the median 200-year water surface elevation plus three feet and not allowed to breach, even if overtopped. Overtopping flows are assumed to leave the channel and remain in the 200-year floodplain.

    b. All project levees and floodwalls are to be modeled to incorporate a minimum crown elevation equal to the authorized (usually the 1955/1957) Corps design profiles – this affects non-urban areas for the most part – all such levees and floodwalls are to be allowed to overtop, act as weirs, and not breach for floods up to and including the median 500-year flood. Overtopping flows are assumed to leave the channel and remain in the 200-year floodplain.

c. Non-project levees and floodwalls in non-urban areas in the region, to the extent they may affect the DWSE, are to be modeled at their existing or authorized height, whichever is higher, and to act as weirs without breaching if overtopped.

d. Bridges with less than three feet of clearance above the DWSE may experience extraordinary debris loading that must be analyzed for pressure flow and backwater impacts on the DWSE in the vicinity of the bridge.

2. Based on judged potential for underestimating the median 200-year water surface elevation, add height to the computed water surface elevation to account for the potential for the new, updated hydrology to yield higher flows. Once it is available, the updated hydrology and hydraulic modeling for the Sacramento-San Joaquin Valley, incorporating sea level rise and climate change considerations, should eliminate the need to consider adding height to the median 200-year water surface elevation.

This modified median 200-year water surface elevation becomes the DWSE.

The physical top of levee (levee crown elevation) or floodwall must be no lower than the DWSE plus a minimum of three feet, or higher, to account for wind setup and wave runup – specific wind-wave analyses need to be completed using the DWSE.

Alternatively, a lower physical top of levee is allowable if the levee (or floodwall) is designed to accommodate overtopping, such as by armoring the landside levee slope and toe. For design of the overtopping protection, the depth of overtopping is to be assumed equal to the amount by which the top of the levee is lower than required (e.g., a levee one foot lower than required should be designed for one foot of overtopping), and the duration of overtopping is to be assumed equal to the time that the water surface elevation for the design hydrograph is within this same amount of the peak stage (e.g., a levee one foot lower than required should be designed for overtopping to occur for the length of time that the design hydrograph is within one foot of its peak stage).

The above procedures should generally result in a conservative DWSE for design of levee systems along streams. However, the civil engineer also needs to consider two other situations: (1) whether upstream levee failures could produce overland flows that would reach the area protected by the levee system or increase the water surface elevation along the levee system, and (2) whether flooding in a nearby leveed area could fill that area and breach a nearby levee, returning flow to the stream and increasing the DWSE for a portion of the levee system.

Option 2: Modified Corps Approach

This approach requires specification of the median 200-year water surface elevation and a description of uncertainty about that elevation. The median water surface elevation from which the DWSE will be established should be computed with a channel model configured as described below, using the median 200-year discharge rate for the design event at the site, along with a description of uncertainty about that discharge (procedures for developing the description of the uncertainty are presented in Corps' publication EM 1110-2-1619 and are included in the Corps' HEC-FDA computer program). The discharge-frequency function from which the required design discharge is to be taken should be the best available function from recent flood-frequency studies. If results of a recent frequency study completed by the Corps or DWR are available, the 200-year discharge rate from that study and the description of uncertainty about that should be used. In the absence of an appropriate discharge rate from such a recent study, the 200-year discharge rate at the site from the 2002 Comprehensive Study may be used, if that is available. Finally, if an appropriate design discharge rate is not available for either a recent Corps or DWR study or the Comprehensive Study, the median 200-year discharge rate and uncertainty about that may be computed by the engineer with appropriate methods. Those methods include fitting a statistical model with unregulated stream flow observations; configuring, calibrating, and applying a watershed runoff model with design precipitation; or applying regional regression equations acceptable to FEMA, Caltrans, the Corps, or DWR.

1. The hydraulic models are to use the following assumptions:

    a. Upstream, downstream, and nearby levees and floodwalls protecting urban areas are assumed to be raised to the median 200-year water surface elevation plus three feet and not allowed to breach, even if overtopped. Overtopping flows are assumed to leave the channel and remain in the 200-year floodplain.

    b. All project levees and floodwalls are to be modeled to incorporate a minimum crown elevation equal to the authorized (usually the 1955/57) Corps design profiles – this affects non-urban areas for the most part – all such levees and floodwalls are to be allowed to overtop, act as weirs, and not breach for floods up to and including the median 500-year flood. Overtopping flows are assumed to leave the channel and remain in the 200-year floodplain.

    c. Non-project levees and floodwalls in non-urban areas in the region, to the extent they may affect the DWSE, are to be modeled at their existing or authorized height, whichever is higher, and to act as weirs without breaching if overtopped.

   d. Bridges with less than three feet of clearance above the median water surface elevation may experience extraordinary debris loading that must be analyzed for pressure flow and backwater impacts on the DWSE in the vicinity of the bridge.

2. Determine the median 200-year water surface elevation and the corresponding 90 percent and 95 percent assurance 200-year water surface elevations with the procedures described above.

3. Based on judged potential for underestimating the water surface elevations, add height to the computed water surface elevations to account for the potential for the new, updated hydrology to yield higher flows. Once it is available, the updated hydrology and hydraulic modeling for the Sacramento-San Joaquin Valley, incorporating sea level rise and climate change considerations, should eliminate the need to consider adding height to the computed water surface elevations.

The 90 percent assurance 200-year water surface elevation, plus the height added in the prior step, becomes the DWSE.

The physical top of levee (levee crown elevation) or floodwall must be no lower than the DWSE or three feet above the median water surface elevation, whichever is higher, or higher for wind setup and wave runup – specific wind-wave analyses need to be completed using the median 200-year water surface elevation. A lower physical top of levee or floodwall is allowed if it is both (1) at or above the 95 percent assurance 200-year water surface elevation, and (2) at least two feet above the median 200-year water surface elevation, plus any additional height needed to account for wind setup and wave runup.

Alternatively, a lower physical top of levee is allowable if the levee (or floodwall) is designed to accommodate overtopping, such as by armoring the landside levee slope and toe. For design of the overtopping protection, the depth of overtopping is to be assumed equal to the amount by which the top of the levee is lower than required (e.g., a levee one foot lower than required should be designed for one foot of overtopping), and the duration of overtopping is to be assumed equal to the time that the water surface elevation for the design hydrograph is within this same amount of the peak stage (e.g., a levee one foot lower than required should be designed for overtopping to occur for the length of time that the design hydrograph is within one foot of its peak stage).

The above procedures should generally result in a conservative DWSE for design of levee systems along streams. However, the civil engineer also needs to consider two other situations: (1) whether upstream levee failures could produce overland flows that would reach the area protected by the levee system or increase the water surface elevation along the levee system, and (2) whether flooding in a nearby leveed area could fill that area and breach a nearby levee, returning flow to the stream and increasing the DWSE for a portion of the levee system.

6.2 Landside Slope Stability Criteria for Intermittently-Loaded Levees

Landside slope stability analyses are to use appropriate phreatic surfaces based on the DWSE and HTOL. A minimum factor of safety of 1.4 is required for failure surfaces based on the DWSE that intersect the levee crown and are greater than one foot deep in the levee slope. A minimum factor of safety of 1.2 is required for failure surfaces based on the HTOL that intersect the levee crown and are greater than one foot deep in the levee slope.

The steady state phreatic surface is generally considered to be appropriate, but a lower phreatic surface may be justified for slope stability analysis depending on the duration of the design hydrograph, the composition and dimensions of the levee, and the levee's performance history. Except for levees with a positive cutoff or internal drainage features, a phreatic surface lower than the steady state phreatic surface is only justified for levee/foundation materials and construction methods that are well-understood and documented. The lowest phreatic surface that could normally be justified for a homogeneous levee would be along a straight line extending from the landside levee toe to the point where the DWSE (or HTOL) intersects the waterside levee slope.

If the phreatic line corresponding to the DWSE or HTOL emerges on a landside levee slope consisting of erodible soils, then remediation will be required to prevent unraveling and progressive slope failure.

6.3 Underseepage Criteria for Intermittently-Loaded Levees

Levee underseepage criteria for intermittently-loaded levees are as follows:

- The underseepage exit gradient for levees is required to be 0.5 or less at the landside levee toe using a steady state seepage analysis for a water surface set at the DWSE. For levees with a landside blanket layer with a saturated unit weight less than 112 pounds per cubic foot (pcf), a minimum factor of safety for underseepage of 1.6 is required at the landside levee toe.

- The underseepage exit gradient is required to be 0.8 or less at the toe of a seepage berm less than 300 feet wide using steady state seepage analysis for a water surface set at the DWSE. If the saturated unit weight of the blanket layer is less than 112 pcf, a minimum factor of safety for underseepage of 1.0 is required at the toe of the seepage berm.

- Engineering judgment should be applied where the DWSE results in an elevated seepage gradient beyond the toe of a 300 foot wide seepage berm (i.e., greater than 0.8 or a factor of safety of less than 1.0 for blanket layer soils with saturated unit weight of less than 112 pcf). Factors that should be included in the engineering judgment include:

  - Performance history of the levee reach based on a review of whether heavy seepage/boils have previously been reported in the vicinity

  - Site specific geomorphic conditions or surficial geologic conditions that could exacerbate or concentrate seepage by construction of an undrained seepage berm

  - Geophysical data, if available, that indicates anomalous subsurface conditions may be present

  - Variability of subsurface conditions along the levee reach based on site specific explorations that confirm blanket layer conditions along the toe of the proposed seepage berm

- Before a computed seepage gradient above 0.8 for the DWSE should be allowed beyond the toe of a 300 foot wide seepage berm, a sensitivity analysis of the seepage model should be performed. This sensitivity analysis should include:

  - Consideration of model boundary conditions

  - Variations in assumed layer permeability/anisotropy

  - Presence of highly permeable underlying layers which may affect the ability to flood fight the condition

  - Empirical relationships such as the creep ratio

- Where a seepage berm is needed, the required minimum berm width is four times the levee height.

- Unless a drainage blanket is provided in the seepage berm with sufficient capacity to accommodate the seepage, the allowable underseepage exit gradient through the combined seepage berm/blanket layer between the levee toe and the seepage berm toe for a water surface set at the DWSE is determined by interpolation, using 0.5 at the levee toe and 0.8 at the seepage berm toe. The evaluation is to be done throughout the seepage berm, paying close attention to areas where the blanket layer is thinnest. If the saturated unit weight of either the blanket layer or seepage berm material is less than 112 pcf, the minimum factor of safety for underseepage through the combined seepage berm/blanket layer is 1.6 at the levee toe and 1.0 at the seepage berm toe, with linear interpolation applying between.

- In order for the levees to be more resilient for higher water levels up to the HTOL, the following criteria apply:

  – Unless a drainage blanket is provided in the seepage berm with sufficient capacity to accommodate the seepage, the underseepage exit gradient at the landside levee toe is required to be 0.6 or less through the combined seepage berm/blanket layer using a steady-state seepage analysis for a water surface set at the HTOL. If the saturated unit weight of either the blanket layer or seepage berm material is less than 112 pcf, the minimum factor of safety for underseepage through the combined seepage berm/blanket layer is required to be 1.3 at the levee toe.

  – For seepage berms less than 300 feet wide designed to have a maximum 0.8 underseepage exit gradient at the berm toe for the DWSE, steady state analyses using water surfaces set at the HTOL will be expected to yield higher gradients and lower factors of safety. In some cases seepage calculations may indicate a factor of safety of less than 1.0. This by itself does not necessarily indicate a lack of resiliency of the levee system as the berm toe is generally a distance of at least four times the levee height from the levee itself. Seepage berms should be able to experience some repairable foundation damage from boils for a limited period during an extreme event without seriously compromising the integrity of the levee. This would be expected to be particularly true for berms wider than 100 feet or so. To meet criteria regarding HTOL resiliency while using seepage berms, sound engineering judgment should be used to evaluate if the safety of the levee would be compromised with elevated seepage exit gradients beyond the berm toe. Factors to consider in this assessment should include:

    - Width and thickness of berm and distance from landside levee toe

    - Thickness and composition of the blanket layer

    - Thickness and characteristics of pervious stratum beneath blanket layer and berm. Extreme caution should be used if thick deposits of relatively clean sands, gravels, or cobbles are present immediately beneath the blanket layer.

    - Duration of the hydrograph corresponding to the HTOL

    - Conservatism of the analysis

  - Exit gradient and factor of safety calculated at both the landside levee toe and at the berm toe for the DWSE

  - Magnitude of increase in average exit gradient, or decrease in factor of safety, at berm toe for the HTOL water surface compared to values obtained using the DWSE. In general, if the berm is less than 100 feet wide, for steady state seepage at the HTOL the allowable exit gradient may increase by up to 20 percent (as compared to the DWSE). For blanket layer soils with a saturated unit weight of less than 112 pcf, if the berm is less than 100 feet wide, for steady state seepage at the HTOL the allowable factor of safety for underseepage may not decrease by more than 10 percent (as compared to the DWSE).

- Underseepage exit gradient and factor of safety criteria also apply within a ditch or depression near either the levee toe or seepage berm toe. Gradient calculations within the ditch or depression must be performed assuming the ditch or depression is not filled with water, unless it can be assured otherwise. Following Corps procedures, for steady state seepage at the DWSE, the allowable exit gradients in the ditch or depression are 0.5 at the levee toe and 0.8 at 150 feet from the levee toe and beyond (300 feet), with linear interpolation applying between. If the underseepage exit gradient in a ditch or depression at least 300 feet from the levee toe exceeds 0.8, sound engineering judgment should be applied in deciding whether the design is acceptable. For steady state seepage at the HTOL, allowable exit gradients in the ditch or depression are 0.6 at the levee toe and may increase by up to 20 percent (as compared to the DWSE) at 100 feet from the levee toe and beyond (300 feet), with linear interpolation applying between. For blanket layer soils in the ditch or depression with saturated unit weights of less than 112 pcf, the factor of safety for underseepage for a water surface at the HTOL should not decrease by more than 10 percent (as compared to the DWSE) at 100 feet from the levee toe and beyond (300 feet), with linear interpolation applying between.

- Instrumentation should also be included at the toe of the seepage berm as part of the remedial construction in order to measure actual piezometric conditions during elevated river stage conditions and compare to seepage model results. Further, the berm design should be "expandable" with sufficient space to either extend the berm footprint or install relief wells at the berm toe if it is deemed necessary in the future.

Notes:

1. In calculating the factor of safety for underseepage, the following equations apply:

$$FS = i_c/i_e$$

$$i_c = (\gamma_s - \gamma_w)/\gamma_w$$

where: FS = Factor of Safety

i_c = critical gradient

i_e = calculated exit gradient

γ_s = saturated unit weight of soil (blanket layer)

γ_w = unit weight of water (62.4 pcf)

2. If relief wells are constructed for seepage control, exit gradient criteria and factors of safety for underseepage must be achieved midway between relief wells.

6.4 Frequently-Loaded Levee Criteria

The Corps' Engineering Manual for the Design and Construction of Levees (EM 1110-2-1913, 30 April 2000) states the following:

> *Embankments that are subject to water loading for prolonged periods (longer than normal flood protection requirements) or permanently should be designed in accordance with earth dam criteria rather than the levee criteria given herein.*

To make the Corps' guidance more specific, a frequently-loaded levee is defined as a levee that experiences a water surface elevation of one foot or higher above the elevation of the levee toe at least once a day for more than 36 days per year on average.

Frequently-loaded levees should include seepage control and crack-stopping features, like those commonly included in earthen dams of similar height, whenever such levees protect urban or urbanizing areas. In general, seepage exiting the landside slope of the levee without being controlled by filter drains is not acceptable.

In addition to levee design criteria for intermittently-loaded levees as provided in other sections of this document, the criteria for frequently-loaded levees include the following more stringent requirements:

- A phreatic water surface lower than that calculated using steady state seepage analysis is not allowed for landside slope stability analyses.
- The minimum allowable landside slope stability factor of safety for steady state seepage at the DWSE is 1.5; and 1.3 for a water surface at the HTOL.
- The minimum allowable rapid drawdown slope stability factor of safety is 1.2 for a pre-drawdown water surface at the DWSE; for analyses of frequent, large tidal fluctuations, the minimum allowable factor of safety is 1.4 for pre-drawdown and post-drawdown water surfaces corresponding to the mean high-high tide and the mean low-low tide from published data, if available. See Figure 1.
- The requirements for seismic stability and the ability to rapidly remediate the levee following an earthquake are more extensive – see section on seismic vulnerability criteria.

Extra caution is advised for frequently-loaded levees that have a ditch near the levee toe.

Frequently-loaded levees also require a higher standard of maintenance to prevent damage from vegetation and burrowing animal activity. Design features such as the incorporation of burrowing animal barriers into slope protection, that aid in lower cost and more reliable maintenance, while not mandated, are encouraged.

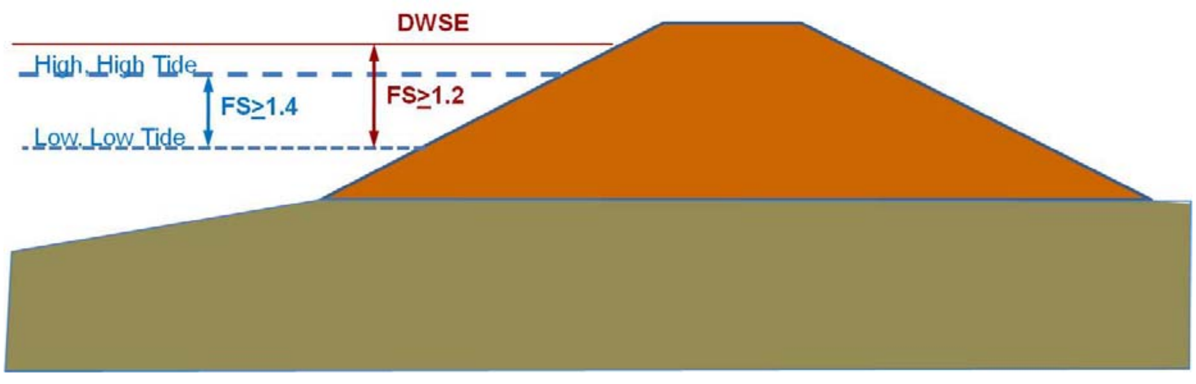

Figure 1. Rapid Drawdown Loading for Frequently-Loaded Levee with Frequent, Large Tidal Fluctuations

6.5 Seismic Vulnerability Criteria

An analysis of seismic vulnerability of the levee system for 200-year return period ground motions is required, using typical summer and winter water surface elevations or mean annual high tide and mean annual low tide over the period of gage record.

Levees and floodwalls that are to be repaired or improved to provide the urban level of flood protection and that are vulnerable to seismic damage should be repaired or improved with alternatives that are more resistant to seismic damage and/or easily and economically repaired following an earthquake over other cost-comparable alternatives (e.g., a berm is usually preferable to a slurry wall). A post-earthquake remediation plan should be part of an emergency action plan that is developed in coordination with pertinent local, State, and federal agencies.

- For intermittently-loaded levees (and floodwalls), if seismic damage from 200-year return period ground motions is expected after the urban level of flood protection is achieved, the post-earthquake remediation plan will be required for quickly restoring the levee system's grade and dimensions (e.g. appropriate crown width and 3h:1v levee slopes) sufficient for protection against the 10-year flood, with three feet of freeboard. To the extent that seismic damage to the levee system would be so significant and widespread that it would be infeasible to restore 10-year protection within eight weeks, seismic strengthening will be required to provide the urban level of flood protection.
- Frequently-loaded levees (and floodwalls), such as many levees in the Sacramento-San Joaquin Delta, are required to have seismic stability sufficient to maintain the integrity of the levee and its internal structures without significant deformation. In most cases, for frequently-loaded levees with less than five feet of freeboard, earthquake-induced deformations should be limited to less than three feet of total deformation and about one foot of vertical settlement. Levees with rigid penetrations or appurtenances may require smaller allowable seismic deformations. Frequently-loaded levees with larger cross-sections and freeboard may be allowed larger seismic deformations subject to engineering analyses and judgment. For frequently-loaded levees, design ground motions higher than the 200-year return period level should also be considered based on the potential consequences of levee failure.

6.6 Levee Geometry Criteria

Minimum levee geometry criteria have previously been specified by various Corps and State guidance documents. The guidance for various minimum levee geometry and their references are as follows in Table 1:

Table 1. Summary of Existing Levee Geometry Guidance

	Corps of Engineers Engineering Manual EM 1110-2-1913 (April 30, 2000)	**Title 23. Waters Division 1. Central Valley Flood Protection Board California Code of Regulations (January 22, 2010)**	**Corps of Engineers Sacramento District Geotechnical Levee Practice REFP10L0 (April 11, 2008)**
Minimum Crown Width (feet)	10	20 (major stream levees) 12 (minor stream levees)	20 (main line, major tributary, and bypass levees) 12 (minor tributary levees)
Minimum Waterside Levee Slope	2h:1v	3h:1v 4h:1v (bypass levees)	3h:1v
Minimum Landside Levee Slope	2h:1v	2h:1v 3h:1v (bypass levees)	3h:1v (new levees) 2h:1v (existing levees with good performance)

For new levees, or levees with extensive reconstruction, situated along major waterways, a minimum 20-foot-wide crown width and 3h:1v waterside and landside slopes (4h:1v waterside slope for bypass levees) will be required. Exceptions may be allowed for reconstruction of existing levees where the authorized geometry provides for a steeper slope or narrower crown, the levee has performed well, and it meets stability and seepage criteria. These geometry requirements represent minimum standards, and wider levee crowns and/or flatter slopes may be necessary in some areas depending upon geologic and geotechnical considerations. At the same time, however, minimum standards should be associated with generally uniform, levee materials and homogeneous embankments. Steeper slopes may be allowed in certain circumstances where there is limited space available, and where levees are demonstrated to meet minimum seepage and stability criteria. Steeper waterside levee slopes may be acceptable where stability criteria are met and either slope protection is provided or it is determined that wavewash erosion for a water surface at or below the DWSE could not result in failure of the levee. For example, levees with slopes steeper than new minimum standards may be acceptable with elements such as central clay cores, slurry cutoff walls, landside filters or drains, or soil reinforcement which substantially decrease seepage hazards and increase slope stability.

The levee prism should be considered to continue underground based on projection of the above-ground levee slopes. The projected levee slopes are useful for evaluating erosion, excavations, and encroachments near the levee.

Levees that are wider than the minimum requirement may have steeper slopes if the minimum required dimensions would fit entirely within the actual levee, and if seepage and slope stability criteria are met (for both deep and shallow failure surfaces).

For extremely wide levees (e.g., more than 50-foot crown width), seepage and slope stability criteria do not need to be met for the outer levee slopes as long as the following criteria are met:

- An analysis must be performed which demonstrates that the anticipated slope failure soil mass would effectively buttress the remaining levee slope to meet stability criteria. The analysis must consider that seepage, sloughing, and erosion can lead to a progressive failure of the levee.

- The central remnant portion of the levee after sliding or slumping of the outer slopes must incorporate a minimum levee geometry cross section (i.e., the minimum required dimensions would fit entirely within the remnant levee mass).

- The combined remnant levee and slumped portions must meet seepage and slope stability criteria for both landside and waterside slopes and for both deep and shallow failure surfaces. Residual soil shear strength parameters must be used along sliding surfaces beneath slumped soil masses.

- For a rapid drawdown condition, the resulting slide mass on the waterside slope should be considered to be eroded away and cannot be relied upon to create a stabilizing or buttressing soil mass.

6.7 Erosion Criteria

The potential for erosion damage must be evaluated and addressed. Erosion damage to riverine levees is usually due to the following conditions: 1) high velocity flows coupled with erosive levee materials and/or poor hydraulic conditions; 2) large waves developed by wind over large, open bodies of water like a bypass; and 3) boat wakes. Erosion hazard is increased by a number of factors, which include:

- Compromised levee prism geometry

- Geomorphologic trends as indicated by channel migration and historical damage

- Loss or narrowing of the natural “berm” located between the levee and stream bank

- Stream flow velocity, depth, duration, and shear

- Wind-wave shear stress
- Levees constructed from erodible materials
- Detrimental hydraulic anomalies, such as encroachments
- Absence of beneficial vegetation or other slope protection

Levees that pose an immediate erosional failure hazard during either a flood or normal flow condition should be repaired based on analysis of the above hazard factors. Similarly, levees that are likely to be significantly damaged during either a flood or normal flow condition should also be repaired. Field surveys of bank conditions and near-bank bathymetry may reveal new or worsened vulnerabilities after high flow events. Performance-based analyses should be considered as well as predictive models. At a minimum, the civil engineer's analyses should consider the annual erosion surveys conducted under the Corps Sacramento River Bank Protection Project and the DWR erosion surveys conducted on the San Joaquin River flood protection system. The downward projection of the theoretical 3h:1v waterside levee slope that stays within the natural stream bank has traditionally been considered to represent a minimum element of slope stability for the overlying levee fill. Figure 2 shows how this projection is made for a typical levee section. When the berm is wider than 35 feet, scour intruding into the projected levee prism would not be considered critical for the Sacramento River Bank Protection Project.

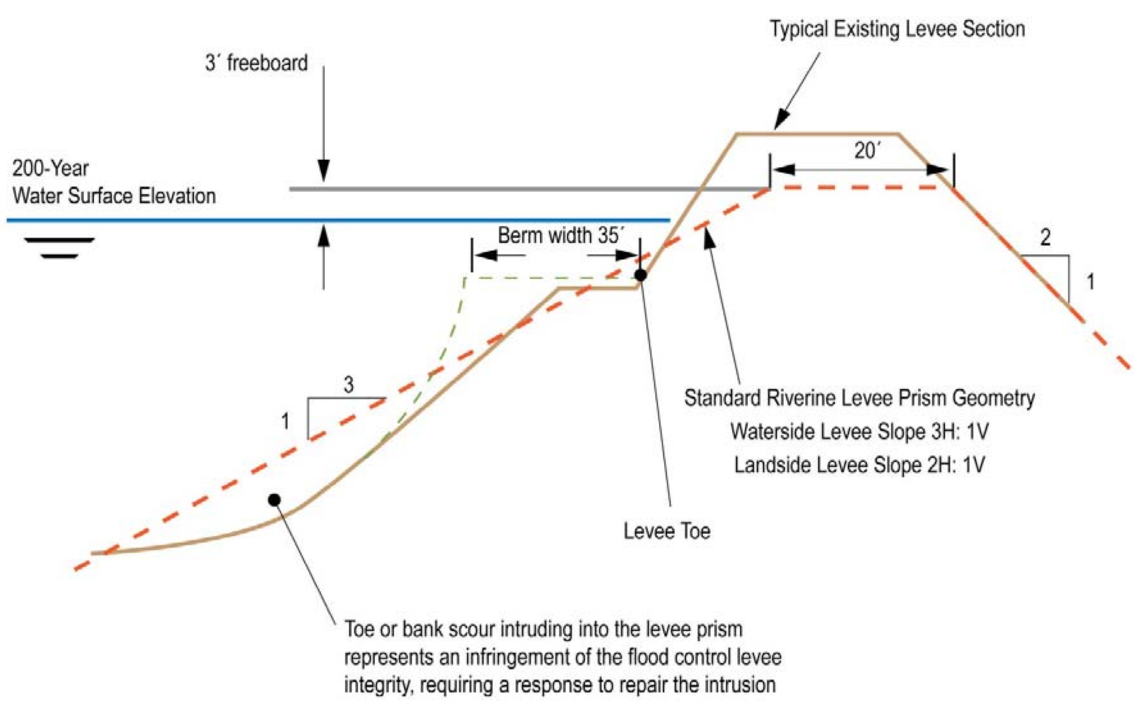

Figure 2. Example of How to Project the Waterside Levee Slope for Determining Acceptable Bank Erosion

Computation of velocities and shear stress for assessment of erosion potential shall use methods described in Corps EM-1110-2-1416, EM 1110-2-1418, and EM 1110-2-1601. In cases for which results from hydraulic models developed for the Sacramento River Bank Protection Project are available from the Corps Sacramento District or from DWR, those may be used.

Design of erosion repairs and erosion protection should conform to guidance in the Corps documents cited above and in the Corps Hydraulic Design Criteria. Procedures for computation of wind setup and wave runup shall conform to requirements identified elsewhere in these criteria. Hydraulic impact analysis should compare the repair condition to pre-erosion conditions (not the existing condition), and be applied to both banks of the river or stream.

6.8 Right-of-Way Criteria

Right-of-way criteria for flood control infrastructure in urban and urbanizing areas should meet the following objectives:

1. Allow adequate room for maintenance, inspection, patrolling during high water, and flood fighting.

2. To the extent practical, adequate right-of-way should be available to provide additional room to expand facilities in the future. Reasons to expand the facilities might include:

    - A desire by the community to provide higher levels of flood protection,

    - Changes in design criteria, poor performance during high water, updated hydrology and/or hydraulics, or other data that would indicate that additional modifications are necessary to maintain the urban level of flood protection.

In order to meet the first objective, it is desirable to hold fee title for the entire levee prism extending from the centerline of the channel to a minimum of 20 feet beyond the landside toe of the flood protection system. Easements are less desirable than fee title. The 20-foot wide landside zone must be maintained as a clear zone for inspection and flood fighting.

In order to meet the second objective, right of way should be secured for a future needs area equal to at least 4 times the levee height or 50 feet, whichever is greater, on the land side of the 20-foot clear zone:

- No structures may be constructed in this future needs area.

- It must also be understood that some seepage is normal and acceptable during high water, so uses incompatible with this seepage should not be allowed in this area.

- The future needs area may be used for open space, agriculture, bike and pedestrian trails, outdoor recreation, parking lots, or other similar uses, but with the understanding that these facilities may be displaced by future levee construction. All grading and construction activities in this area require a report from a civil engineer stating that "the proposed improvements will not have an adverse impact on the integrity/operation of the flood control system."

City and county building restrictions should be adopted which restrict excavations beyond the future needs area. Excavation or grading may be allowed as long as it does not adversely affect the functioning of the levee or floodwall. As a general guide, the bottom of an excavation should not extend below a plane that starts at the boundary of the right of way and extends downward at a 10h:1v slope. Any excavation or grading that extends below this plane requires a report from a civil engineer stating that the proposed or existing activities or features "will not have an adverse impact on the integrity/operation of the flood control system." Furthermore, any excavation or grading above this plane must not adversely affect the functioning of the levee or floodwall and, depending on the circumstances, may need to be analyzed by a civil engineer with a report stating that the proposed or existing activities or features "will not have an adverse impact on the integrity/operation of the flood control system."

For existing developed areas where little to no landside easement exists and acquisition would be excessively difficult and/or costly, the city or county, in cooperation with appropriate local, state, and federal agencies, should develop a long term plan to acquire the minimum space necessary for maintenance, inspection, patrolling, and flood fighting. This plan should be included in the city or county planning documents and General Plan. As part of this determination the following factors should be considered: height of flood protection feature, historic performance, waterside berm width and types of obstruction close to the levee (buildings, fences, pools, vegetation, etc). In general, the minimum width should be no less than 20 feet maintained as a clear zone.

For urbanizing areas adjacent to levees, cities and counties should consider developing more aggressive setback criteria that keeps permanent structures away from the levees. The criteria should also limit actions that could have adverse effects on the performance of the levee system or restrict future modifications to the levee system. Setback distances could range from 70 to 400 feet depending on the height of the levees, future plans for the levee system, and other site-specific conditions.

6.9 Levee Design Criteria Summary

Levee design criteria for the two design options are summarized in Tables 2 and 3, for intermittently-loaded and frequently-loaded levees, respectively:

Table 2. Levee Design Criteria Summary for Intermittently-Loaded Levees

Parameter	Criteria			
DWSE (Option 1)	Median 200-year WSE			
DWSE (Option 2)	90% assurance 200-year WSE			
TOL (Option 1) for hydraulic criteria	Median 200-year WSE + higher of (1) 3 feet, or (2) height for wind setup and wave runup			
TOL (Option 2) for hydraulic criteria	Lower of A or B, where: • A is the higher of (1) 90% assurance 200-year WSE, (2) median 200-year WSE plus three feet, or (3) median 200-year WSE plus height for wind setup and wave runup • B is the higher of (1) 95% assurance 200-year WSE, (2) median 200-year WSE plus two feet, or (3) median 200-year WSE plus height for wind setup and wave runup			
HTOL (Option 1) for geotechnical criteria	Lower of (1) median 200-year WSE plus three feet, or (2) median 500-year WSE			
HTOL (Option 2) for geotechnical criteria	Lower of (1) median 200-year WSE plus three feet, (2) physical top of levee if it is equal to or higher than the 95% assurance 200-year WSE and at least two feet above the median 200-year WSE, or (3) median 500-year WSE			
Seepage - Exit Gradient at Levee Toe	For DWSE		For HTOL	
	$\gamma \geq 112$ pcf	$\gamma < 112$ pcf	$\gamma \geq 112$ pcf	$\gamma < 112$ pcf
	$i \leq 0.5$	FS ≥ 1.6	$i \leq 0.6$	FS ≥ 1.3
Seepage - Exit Gradient at Seepage Berm Toe	$i \leq 0.8$	FS ≥ 1.0	<20% FS degradation for berms less than 100 feet	<10% FS degradation for berms less than 100 feet
Steady State Slope Stability	FS ≥ 1.4		FS ≥ 1.2	
Seismic Vulnerability	Restore grade and dimensions for at least 10-year WSE plus three feet of freeboard or higher for wind setup and wave runup within eight weeks			
Levee Geometry	For new or extensive reconstruction on a major stream, minimum 20-foot-wide crown, 3h:1v waterside and landside slopes for all levees except bypass levees (4h:1v waterside slope)			

Note: The median 200-year WSE, the 90% assurance 200-year WSE, and the 95% assurance 200-year WSE in this table are assumed to have been increased appropriately to account for the potential for new, updated hydrology to yield higher flows.

Key:
DWSE = design water surface elevation
FS = factor of safety
HTOL = hydraulic top of levee
i = exit gradient
pcf = pounds per cubic foot
TOL = top of levee
WSE = water surface elevation
γ = unit weight of soil

Table 3. Levee Design Criteria Summary for Frequently-Loaded Levees

Parameter	Criteria	
	For DWSE	For HTOL
Steady State Slope Stability	FS ≥ 1.5	FS ≥ 1.3
Minimum Allowable Rapid Drawdown Slope Stability	FS ≥ 1.2	
Frequent, Large, Tidal Fluctuations Rapid Drawdown Slope Stability	FS ≥ 1.4*	
Seismic Vulnerability	No significant deformation, usually limited to three feet maximum with one foot of vertical settlement.	

Notes:
These criteria are additions or exceptions to the criteria presented for intermittently-loaded levees.
*Applies for the range of tidal fluctuation, not the DWSE
Key:
DWSE = design water surface elevation
FS = factor of safety
HTOL = hydraulic top of levee

7.0 Other Criteria under Development

The criteria presented below are intended to solicit agency and public comment for further development in subsequent versions of the ILDC. In addition, the criteria presented in Sections 7.9, 7.10, 7.11, 7.12, and 7.13 may be revised further through a related process underway to establish criteria for a city or county to make a finding that the urban level of flood protection exists in areas that may not rely on levees or floodwalls.

7.1 Encroachments (Excluding Penetrations, Closure Structures, and Levee Vegetation)

Encroachments need to be assessed by a civil engineer to determine whether they pose a hazard. Encroachments must not increase geotechnical hazard or decrease hydraulic capacity of the channel beyond that required for the urban level of flood protection, or impair maintenance, inspection, or flood fighting. All non-permitted encroachments should be either properly permitted or removed, depending on the assessment. In order to assess encroachments, the civil engineer needs to identify the following information: maintaining entity, owner, levee mile (LM) and Global Positioning System (GPS) location, Board or local permit number (if applicable), type, age, condition, and performance history.

All new encroachments must meet current Corps/Board requirements for design and construction. All new encroachments should be properly permitted.

In cases where the levee dimensions exceed the minimum levee geometry requirements by more than an order of magnitude, encroachments that may not otherwise meet Corps/Board requirements should be assessed for hazard on the basis of their actual geotechnical and/or hydraulic impact.

7.2 Penetrations

Assessment of Existing Penetrations - Penetrations typically include pipe crossings as well as transportation structures. Penetrations have the potential to produce rapid failures of levees as they can provide a preferential seepage path or an open conveyance for floodwaters.

In order to assess pipe penetrations, the civil engineer needs to provide the following information on known penetrations: maintaining entity, LM and GPS location, Board permit number (if applicable), type of utility, owner, pipe diameter, pipe material type, pipe backfill type and method, depth below DWSE, age, and performance history. In addition, the civil engineer needs to provide an estimate of the design life of each penetration. In order to assess transportation penetrations (e.g., a roadway crossing of a levee below the elevation of the adjacent levee crown), the civil engineer needs to provide the following information: maintaining entity, LM and GPS location, Board permit number (if applicable), type of corridor, width of corridor, structural section thickness' and types, and associated closure structure type and location.

A hazard assessment shall be performed for each penetration. Hazard will be quantified into low, medium, and high categories. Penetrations with a medium hazard shall be monitored. Penetrations with a high hazard need to have a full engineering evaluation to demonstrate that the hazard is acceptable.

Section 8.1 of EM 1110-2-1913 provides guidance on factors to consider in evaluating penetrations through levees. These include the height of the levee, the duration and frequency of high water stages against the levee, the susceptibility to piping and settlement of levee and foundation soils, the type of pipeline (low or high pressure line, or gravity drainage line), the structural adequacy of existing pipe and pipe joints, and the adequacy of the backfill compaction, the feasibility of providing closure in event of ruptured pressure lines or failed flap valves in gravity lines during high water, the ease and frequency of required maintenance, the cost of acceptable alternative systems, possible consequences of piping or failure of the pipe, and previous experience with the owner in constructing and maintaining pipelines.

This guidance can be used to categorize the hazard level of penetrations. For example, a high hazard category should be assigned to a penetration that has all of the following characteristics:

- A pressure line
- Constructed of degradable/corrodible materials (e.g., wood, corrugated metal pipe (CMP))
- Considerably aged or not well maintained
- Below the DWSE

Assessment of Unknown Penetrations - To identify potentially unknown pipe penetrations, the civil engineer shall conduct a study using land based continuous levee crown geophysical methods with a capability of assessing the levee material and the upper 20 feet of foundation materials. Pipe penetrations that are located from this survey shall have the above assessment of existing penetrations procedures followed and also be reported to the appropriate permitting agency for enforcement action.

New Penetrations - All new penetrations shall meet current Corps guidance for design and construction. Additional guidance for abandoning penetrations and addressing seepage along penetrations is envisioned in subsequent versions of the ILDC.

7.3 Floodwalls, Retaining Walls, and Closure Structures

Current Corps design guidance for special features such as floodwalls, retaining walls, and closure structures shall be followed. This information is included in Corps' EM 1110-2-1913, EM 1110-2-2502, EC 1110-2-6067, and ETL 1110-2-571. Because design considerations for floodwalls and closure structures are still evolving since the 2005 New Orleans flood, caution should be used when designing and assessing these structures. All global slope stability and embankment through-seepage and underseepage safety criteria requirements for either the "Modified FEMA Approach" or "Modified Corps Approach" design water surfaces shall be applicable for floodwalls, retaining walls, and closure structures on levees.

Floodwalls and retaining walls should only be used where it is impractical to use a conventional earth embankment, such as where there is insufficient space due to pre-existing improvements. If floodwalls are proposed, it is preferred they only be used primarily along the levee crest for supplemental freeboard.

For closure structures, the civil engineer needs to provide the following information: maintaining entity, LM and GPS location, Board permit number (if applicable), structure details, length of time to close structure, location and type of materials for closure, structure dimensions, age, and performance history.

Closure structures shall be tested at least once a year prior to the flood season so that crews responsible for implementing the structures are familiar with their operation and to provide that all parts are present and in working order.

7.4 Levee Vegetation

Policies regarding removing trees and other woody vegetation that have grown and matured on levees are evolving and will be informed by ongoing and future research. DWR is committed to developing flood risk reduction solutions that also meet environmental goals. Pending the Board’s adoption of the CVFPP, the following interim minimum criteria are to be used for managing vegetation on levees protecting urban and urbanizing areas in the Sacramento-San Joaquin Valley:

- New levees and recently cleared levee slope areas will be maintained to not allow new woody vegetation to establish on the slopes and within 15 feet of the levee toe (or the existing easement width). In certain circumstances, woody vegetation may be allowed on portions of the waterside slope and riverbank or berm for a newly graded or constructed levee if a specially designed waterside planting berm is added. This planting berm must represent an over-built section with respect to minimum geometries, and be of sufficient size and configuration to serve to mitigate potential negative impacts to levee safety with respect to seepage, stability, and erosion criteria should either windfall or root decay occur.

- For levees that have existing trees and other woody vegetation, an engineering inspection and evaluation shall be conducted to identify trees and vegetation that pose a clear and unacceptable threat to the integrity of the levee. One such example of a tree to be removed would be a large-diameter (e.g. three feet) tree located near the top of a relatively narrow or short levee (e.g. less than 10 feet) which, if blown over, the tree's root ball could take out a significant portion of the levee cross section.

- Based on the engineering inspection and evaluation, trees and other woody vegetation that pose an unclear threat need not be removed without further analysis of the potential hazard that would justify removal. If not removed, close monitoring of these trees is necessary; for example, an arborist could occasionally observe them during high winds after significant rainfall.

- Existing trees shall be trimmed/thinned and immature trees shall be removed from all of the following areas:

  – Levee crown

  – Landside levee slope

  – Within 15 feet of the landside levee toe (or existing easement width)

  – Within the upper 20 feet (slope distance; vertical elevation interval equivalent to about upper seven feet) of the waterside levee slope

- The trimming and thinning shall be done in accordance with DWR's Interim Vegetation Inspection Criteria for Standard Levees, October 2007. Brush, weeds, or other vegetation over 12 inches high blocking visibility and access within these levee areas should be trimmed, thinned, mowed, burned, dragged, sprayed with herbicide, or otherwise removed.

- The immature trees to be removed from these areas would typically be less than 4-6 inches in diameter at breast height.

- Remove dead trees.

- When removing any tree, dead or alive, at a minimum remove all roots larger than one and one-half inches in diameter that are within three feet of the tree trunk. More extensive root removal may be required, depending upon the location, size, and type of tree; the quantity, orientation, and size of the roots; the dimensions of the levee (or floodwall); and the composition of the levee and foundation. The resulting excavation shall be backfilled with engineered fill using appropriate placement, moisture conditioning, and compaction methods.

In addition to the above measures, levee owners are encouraged to take the following actions over the long term beyond 2012:

- Develop a long-term vegetation life cycle management plan that allows for the eventual elimination of trees and other woody vegetation on the levee crown, landside slope, and within 15 feet (or existing easement width) of the landside toe. This plan would allow trees and other woody vegetation beyond a certain size to live out their normal lives on the landward portion of the levee, and then upon their deaths, would be removed and their root balls and roots appropriately remediated on an individual basis.

- Trees and levee vegetation may be preserved over the long term if they provide critical habitat or erosion protection on the waterside slope and bank, by including the following root mitigation alternatives as part of any levee improvement program:

  - where feasible, the overall width of the levee should be widened landward by at least 15 feet beyond the standard minimum levee dimensions, or

  - an effective root or seepage barrier is installed within the upper 10-15 feet of the levee crown in order to mitigate potential impacts by tree roots.

The above criteria and encouraged actions are intended to build upon the March 29, 2009 California Central Valley Flood System Improvement Framework developed by the California Levees Roundtable and set up the levee system to meet the requirements of a regional variance from Corps national vegetation policy in the long term.

7.5 Wind Setup and Wave Runup

Wind wave analysis is required, as noted elsewhere in these criteria. The wind setup and wave runup distances must be computed and added to the median 200-year still water surface elevation to determine the required elevation of the physical top of levee or floodwall. The setup and runup also must be computed and considered for analysis of erosion and overtopping impacts.

While the civil engineer has discretion in selection of the method to use, guidance for computing setup and runup distances is provided in the Corps' Coastal Engineering Manual, the Corps' Shore Protection Manual, and EC 1110-2-6067. Other guidance is provided in FEMA (2008), FEMA (2005), and EurOtop (2007).

The setup and runup computations require specification of potential wind speed and direction, fetch length, and water depth along the fetch. Standard practice should be followed to determine fetch length and water depths for the computations, consistent with the references cited above.

The wind speed to be used for setup and runup computations is based on design practice for bank protection on the Sacramento River. The wind speed to be used is that which has a 50 percent probability of not being exceeded in any 50-year design period. This criterion yields a design wind speed with a return period of 72.6 years, or annual probability of 0.0138. This design wind speed should be used for design of levees covered by the criteria in this document. Per Corps guidance, a limited amount of levee overtopping can be allowed without armoring, depending on levee geometry, soil conditions, and ground cover; typically ranging between 0.01 cubic feet per second per foot (cfs/ft) and 0.1 cfs/ft.

To estimate the maximum wave runup for setting the elevation of the physical top of the levee or floodwall, a design wind speed duration of less than one hour should be used, consistent with historical bank protection design.

For setup and runup computations for erosion protection design, and particularly for estimating median stone weight for armoring a levee, the duration of the wind should be the shortest length of time that would yield significant levee erosion; four and six hour durations have been used previously by the Corps along the Sacramento River.

In performing these computations, the civil engineer should consider the duration of the hydrograph and that this method is based on open water and can result in excessive wave heights for riverine environments. Civil engineers should use caution in specifying excessive freeboard until further research is performed. Based on the long history of performance of the Sacramento River Flood Control Project, six feet of freeboard should be considered sufficient except in extremely unusual circumstances.

7.6 Security

Appropriate measures need to be taken to protect urban and urbanizing area levee systems from acts of terrorism and other malicious or negligent acts. DWR intends to work with local, State, and federal agencies to develop an array of security measures, including a set of minimum required security measures, for application on urban and urbanizing area levees and floodwalls. These measures may include, but not be limited to, improved public awareness, vulnerability and threat assessments, suspicious activity reporting, and inclusion on federal and State Critical Infrastructure lists. Documentation and discussions regarding these security measures may qualify for Freedom of Information Act exclusion under federal and State laws such as the Protected Critical Infrastructure Information (PCII). Any public discussion or documentation of the full range of security measures, or of specific security measures applicable for any given levee or floodwall system, will need to be managed in a manner that maintains the integrity and effectiveness of the measures to the maximum extent possible.

7.7 Sea Level Rise

The effects of sea level rise are to be estimated and addressed for the duration during which a finding that the urban level of protection exists may be valid. For example, if the effect of sea level rise on the levee or floodwall is estimated to be one inch during the duration in which a finding may be valid, then the levee or floodwall design must be for the DWSE that includes the inch of sea level rise. It is advisable to consider a range of estimates and prepare for future expansion and structural raises to address long-term sea level rise.

The effects of sea level rise in the Delta and Suisun Marsh are estimated in Section 14 of the Delta Risk Management Strategy Final Phase 1 Report, dated February 2009, available at:

http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/phase1_information.cfm

Corps guidance is provided in EC 1165-2-211 dated July 1, 2009.

7.8 Emergency Actions

Although emergency actions, such as flood fighting, are expected to be employed as needed to prevent levee and floodwall failures wherever feasible, they may not be relied upon for finding that the urban level of protection exists for an area. There are two exceptions:

1. Closure structures that meet the requirements contained in the “Floodwalls, Retaining Walls, and Closure Structures” section may be assumed effective and relied upon for performing as designed.

2. Flood relief structures such as culverts, gates, weirs, pumping plants, and levee relief cuts may be assumed effective and relied upon for performing as designed provided they have an approved plan in the operation and maintenance manual (and/or the emergency action plan) for the project. The following requirements would apply:

    - The plan must have specified triggers, procedures, and responsible agencies.

    - Such flood relief structures may only be used to reduce the extent and/or depth of flooding within the protected area in the event a levee or floodwall failure has occurred (e.g., an area may have some levees or floodwalls that provide the urban level of flood protection and other levees or floodwalls that do not – the levees or floodwalls that do not provide the urban level of flood protection must be assumed to fail (with an appropriately sized breach) during the 200-year flood and an opening structure may limit the extent and/or depth of flooding within the protected area).

- The plan must be found to be clearly feasible for all levee and floodwall failure scenarios during which the plan would need to be executed.

- Pumping plants must be designed to operate up to the full depth of potential flooding and have a dependable backup power supply.

- In the case of levee relief cuts, the plan must also include location(s), dimensions, and equipment (with identification of reliable sources of the equipment in time of emergency) and may not rely on flood waters to aid in making the relief cut.

- The plan must identify the hydraulic impacts of using the flood relief structure and specifically be approved as part of the finding that the urban level of flood protection exists.

- If such a plan is approved, it may be used to lower the ponded water surface in the flooded areas of the basin based on the hydraulic capacity of the flood relief structure(s) and the most severe levee or floodwall failure scenario that is reasonably expected. In the case of levee relief cuts, the ponded water surface may be no lower than the levee crown elevation (due to the higher uncertainty associated with this type of flood relief structure), except as additional capacity for relief is provided by other fixed flood relief structures, such as culverts. Without a flood relief structure in an approved plan, the assumed ponding depth must be the depth resulting from the most severe levee or floodwall failure scenario that is reasonably expected. If that depth would exceed the top of the levee or floodwall, weir flow over the top of the levee or floodwall is to be assumed.

7.9 Procedure for Finding that Facilities Provide the Urban Level of Flood Protection

A city or county must make a finding that the urban level of flood protection (i.e., 200-year protection) exists for a specifically identified area, before:

1. entering into a development agreement,

2. approving any discretionary permit or other discretionary entitlement, or any ministerial permit, or

3. approving a tentative map, or a parcel map for which a tentative map was not required, for any subdivision within any urban area or urbanizing area in the Sacramento-San Joaquin Valley that relies on a levee or floodwall for providing the urban level of flood protection.

The city or county's finding must be based on substantial evidence in the record as described in Section 7.10. Any such finding shall be valid for a period of up to 20 years, based upon the following considerations:

- The need for cities and counties to have a degree of certainty in planning for development in the area protected by the levee or floodwall.

- The need to provide continued public safety by periodically reevaluating levee systems in light of changing engineering standards and practice, changing hydrology, sea level rise, climate change, physical changes in the system, and levee system performance.

After 20 years without a new finding that the urban level of flood protection exists, the finding is deemed to have expired and the urban level of flood protection deemed not to exist. A new finding may be made at any time prior to or after expiration of an earlier finding, following the standard for substantial evidence in the record; the new finding would establish a new time period of up to 20 years during which the urban level of flood protection is deemed to exist, provided that the facilities continue to be well maintained and repaired if damaged, in compliance with periodic review requirements as described in Section 7.12. This procedure provides cities and counties the opportunity to identify and time to rectify any inadequacies many years prior to expiration of the finding.

Nothing herein should be interpreted as restricting the State's authority to require that a city or county meet revised or additional criteria within a reasonable timeframe in the event of an emergency (e.g., imminent threat to life or property) or through the rulemaking process.

7.10 Substantial Evidence in the Record

Substantial evidence in the record must include all of the following:

1. A report by a civil engineer that determines that the urban level of flood protection exists for the specifically identified area, based on the ILDC. The report must address agency and public comments, after providing a minimum of 30 calendar days after public notice for submitting comments. The report must also address any prior recommendations by an independent expert panel. The report is available for the purposes of this Section for up to one year.

2. A report by an independent expert panel (as described in Section 7.13) that considers the civil engineer's report and determines whether the urban level of flood protection exists for the specifically identified area. If the panel determines that the urban level of protection does not exist, the report must state the reason(s) for this determination.

3. If the independent expert panel determined that the urban level of protection does not exist, a final report by the civil engineer that addresses the panel's determination and reason(s). The final report must determine that the urban level of flood protection exists for the specifically identified area.

4. If the independent expert panel determined that the urban level of protection does not exist, a letter from the panel to the city or county stating whether the expert panel concurs with the determination made in the civil engineer's final report that the urban level of flood protection exists.

5. Documentation of any exceptions to the ILDC, following the procedure in Section 7.11.

7.11 Exceptions

Because it is infeasible to establish criteria that will be applicable to all situations, the following procedure can be used for providing exceptions from the criteria contained in this document (excluding criteria contained in Sections 7.9, 7.10, this Section, 7.12, and 7.13). An exception can be provided by agreement of: (1) the civil engineer responsible for the report determining that the urban level of flood protection exists, and (2) a majority of the independent expert panelists with expertise in the subject area of the exception, with no less than two of the panelists with expertise in that subject area agreeing to the exception.

Agencies and the public must be afforded a minimum of 30 calendar days after public notice to comment on the exception(s). The report by the civil engineer must (1) identify each exception, (2) provide the reason(s) for agreeing to the exception, and (3) address agency and public comments on the exception(s). The independent expert panel's report must identify the panelists that agree to the exception(s) and provide any minority opinions of the panel.

In situations where it is unclear whether criteria are met or an exception is needed, upon request of the civil engineer or the independent expert panel, DWR may provide a written opinion indicating whether an exception is needed or advised.

7.12 Periodic Review

The finding made pursuant to Section 7.9 is only valid as long as a periodic review by a civil engineer determines, and the city and/or county determine(s) within six months of the civil engineer's determination, that the levee system is being adequately operated and maintained and that integrity of the levee and/or floodwall facilities has not degraded to the point that the urban level of flood protection, as defined at the time of the finding, no longer exists. Prior to the city and/or county making such a determination, the city and/or county shall provide public notice and make the civil engineer's determination and accompanying report available for agency and public comment for at least 30 days. The city and/or county must consider and address comments prior to making the determination.

If damage has occurred or maintenance inadequacies have been identified since the finding was made, the civil engineer must determine whether the damage or maintenance inadequacies have compromised the levee system and to what extent, as measured in terms of level of protection following the criteria in use at the time of the finding and assuming the criteria result in protection against the 1-in-200 annual chance flood (i.e., 200-year protection). If the civil engineer has determined that the damage or maintenance inadequacies compromise the ability of the levee system to provide the urban level of flood protection, the city and/or county may still determine that the levee system is being adequately operated and maintained and that the urban level of flood protection continues to exist, provided the city's and/or county's determination includes all of the following information:

1. Nature and extent of the damage and/or maintenance inadequacies.
2. Plan, schedule, and cost estimate for remediating the damage and/or maintenance inadequacies.
3. Funding source(s) and amount(s) available for remediating the damage and/or maintenance inadequacies.
4. Any extraordinary measures that will be taken to address public safety while the damage or maintenance inadequacies remain unremediated.
5. Entities responsible for performing the remediation or extraordinary measures, along with written concurrence from each entity as to their responsibilities.

The plan and schedule must be responsive to the severity of the damage or maintenance inadequacies and provide for rapid remediation of damage or maintenance inadequacies that are temporarily resulting in a low level of flood protection as compared to 1-in-200 annual chance protection. If all of the identified damage or maintenance inadequacies are not remediated prior to completing the next periodic review, the finding that the urban level of flood protection exists is deemed to have expired and the urban level of flood protection deemed not to exist.

7.13 Independent Expert Panel

An independent panel of experts is to perform an independent review in compliance with EC 1165-2-209 dated January 31, 2010, following the procedure for Type II Independent External Peer Review, to the extent applicable, with a minimum of three independent expert panelists: at least one panelist with expertise in hydrology and hydraulics, and at least two panelists with expertise in levee or floodwall design and construction, as appropriate for the project. No more than one of the panelists may have served on the independent expert panel that prepared the report used for the most recent previous finding by the city and/or county that the urban level of flood protection exists for the levee system or specifically identified area under consideration.

8.0 Inspection, Monitoring, and Remediation of Poor Performance

It is almost never practical or possible to completely know all of the engineering properties of levees and their foundations. Consequently, there will almost always be some degree of uncertainty that justifies both robust regular inspections and flood stage monitoring programs for levees and floodwalls protecting urban and urbanizing areas, with all of the attendant appurtenances and features. Any levee or floodwall that shows distress should be remediated before the next flood season.

At a minimum, the Corps standard inspection requirements for project levees are applicable for all levees and floodwalls considered to provide the urban level of flood protection, including that a public agency (or agencies) routinely operates and maintains the levee system and inspects the entire levee system at least every 90 days and after every high water event. Damage and maintenance inadequacies identified from these inspections should be prioritized and addressed in a timely manner, not awaiting the periodic review process.

Although the criteria are aimed toward a goal of providing for the primary hazard of levee failure to be from overtopping, rather than slope instability or seepage, this goal is balanced against cost concerns, so that only the most marginal of levee projects would have their feasibility jeopardized by the requirements of the ILDC. Consequently, the ILDC allow for some levees to be designed for a finding of the urban level of flood protection without necessarily providing strict design measures that eliminate the potential for failure before overtopping occurs (e.g., levees that are significantly higher than the HTOL, levees with exit gradients at the toe of a seepage berm slightly exceeding the critical exit gradient for water at the HTOL, and levees with exit gradients at the toe of a 300-foot wide seepage berm exceeding the critical exit gradient for water at the DWSE). In these situations, if the engineering properties have been properly characterized and there is no additional conservatism in the computations, signs of distress (such as boils), can be expected before overtopping occurs. Left unattended, sustained boils could cause enough internal erosion to damage the seepage berm and even possibly cause a levee breach. Consequently, a flood stage monitoring program is even more justified.

Civil engineers that design levee systems in urban and urbanizing areas must also incorporate features that provide for prompt identification of distress during and after a high water event. Such features include all-weather roadways that allow visual inspection of the levee slope and toe area, the seepage berm, and the seepage berm toe area. The roadways need to be designed and constructed to sustain heavy construction vehicles needed for effective flood fighting in wet conditions.

Levee designs also need to incorporate piezometers, and possibly other types of instrumentation, to verify design computations and adjust for actual field conditions. Remediation may be needed, based on either instrumentation readings or poor field performance during high water conditions.

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